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New Bedford Harbor Long Term Monitoring Survey III: Summary Report

Submitted to

U.S. Army Corps of Engineers, New England District
696 Virginia Road
Concord, Massachusetts 01742-2751

Prepared by

ENSR INTERNATIONAL

Under

Contract No. DACW33-96-D-0004
Task Order No. 037

March 2001

Certification

This submission has been subjected to internal review in accordance with ENSR's review and coordination procedures to ensure:

(a) completeness for each discipline commensurate with the level of effort required for the submission

(b) elimination of conflicts, errors and omissions, and

(c) the overall professional and technical accuracy of the submission.

Signed for ENSR

Signature James A. Blake

Name James A. Blake

Title Senior Program Manager

Date 23 February 2001

Signature

Name Dion Lewis

Title Senior Marine Chemist

Date 7 MARCH 01

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1.0 INTRODUCTION

The New Bedford Harbor (NBH) Superfund Site, located in southeastern Massachusetts, extends from the shallow northern reaches of the Acushnet River estuary south through the commercial harbor of New Bedford and into 17,000 adjacent acres of Buzzards Bay. Industrial and urban development surrounding the harbor has resulted in sediments becoming contaminated with high concentrations of many pollutants, notably polychlorinated biphenyls (PCBs) and heavy metals, with contaminant gradients decreasing from north to south. From the 1940s into the 1970s, two electrical capacitor manufacturing facilities, one located near the northern boundary of the site and one located just south of the NBH hurricane barrier, discharged PCB wastes either directly into the harbor or indirectly via discharges to the city's sewerage system.

Currently on the National Priorities List (NPL), the harbor has been divided by the U.S. Environmental Protection Agency (EPA) into three study areas: the upper, lower, and outer harbors. The upper harbor is the most contaminated segment, with historical PCB concentrations recorded up to 100,000 ppm. This area and adjacent sites in the lower and outer harbor are closed to commercial and recreational fishing. Because of the potential danger to human health, a remediation plan is underway to remove PCB-contaminated sediments from the harbor. Approximately 14,000 yd^3 of the most contaminated sediment in the upper harbor were removed in 1994 and 1995. Planning is currently underway to remove the remaining contaminated sediment beginning in late 2002.

In an effort to assess the effectiveness of the Superfund remedies, a long-term monitoring (LTM) plan was developed by the EPA's Research Laboratory, Atlantic Ecology Division (EPA/AED) in Narragansett, Rhode Island. The LTM project focuses on the ecological health of the sediments and includes collection of data on sediment chemistry, grain size, toxicity, and benthic infauna. A limited hydrographic effort was also performed to measure temperature, salinity, and dissolved oxygen from water near the bottom at each of the sediment stations.

Two previous sampling rounds for this program include baseline sampling conducted in October 1993 (LTM I) and a second event (LTM II) conducted immediately after removal of the "hot spot" sediments in October 1995. LTM III, conducted from September to November 1999, represents the third sampling round of the EPA/AED plan. Sampling was conducted at 79 separate stations located in the three areas of New Bedford Harbor. The main parameters measured in the monitoring program include acid volatile sulfide, nine metals, 18 PCB congeners, total organic carbon, and sediment grain-size composition; sediment is also collected for assessing toxicity and for developing benthic community data. A review of the history of PCB contamination and remediation efforts in NBH together with a summary of the long-term monitoring strategy and results of the 1993 survey are presented in Nelson et al. (1996).

EPA New England has overall responsibility for all phases of the study. EPA/AED developed the sampling design, provided technical support, and participated in quality assurance oversight. The U.S. Army Corps of Engineers (USACE) was responsible for implementing LTM III, including oversight of USACE's contractor, ENSR, who performed the field sampling, oversaw sample analysis, and prepared the report. Boat services and laboratory analyses for chemical, physical, and biological parameters were provided under subcontract to ENSR.

2.0 METHODS

2.1 Quality Assurance

Quality Assurance (QA) for this project is presented in detail in the Quality Assurance Project Plan (QAPP) developed for this project (ENSR, 1999). As part of the QA program, the ENSR QA Officer, Ms. Debra McGrath, conducted field audits in order to ensure that the field team understood and was using the appropriate methodology for field sampling; audited the subcontractor laboratories performing the chemistry and toxicology analyses; and validated the entire data set before it was submitted.

2.2 Field Methods

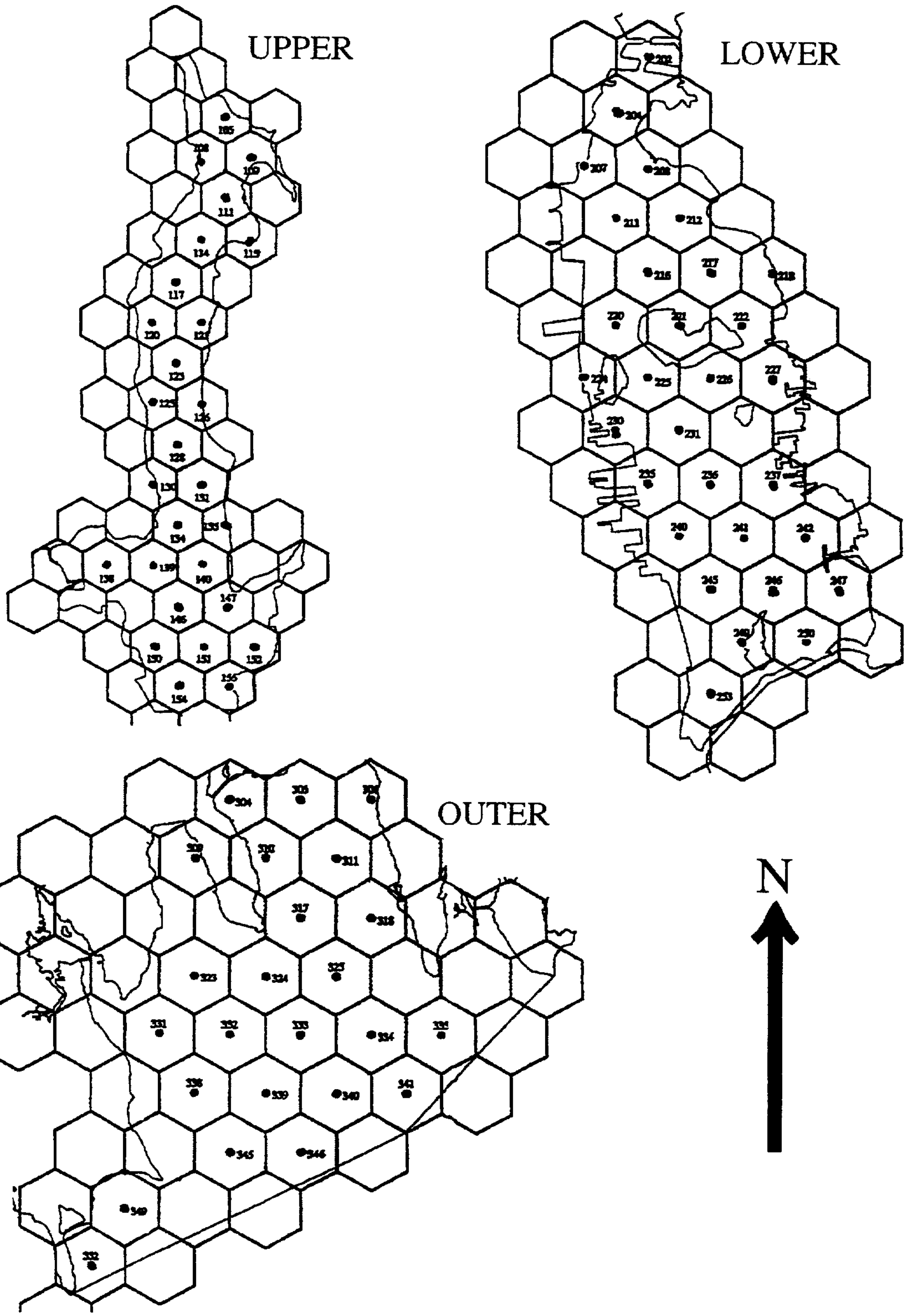
The areal coverage and sampling strategy was based on a format originally developed as part of the Environmental Monitoring and Assessment Program (EMAP) as implemented for the baseline sampling conducted in 1993 (Nelson et al., 1996):

- ***Segment 1*** (Upper Harbor) included the area north of the Coggeshall Street Bridge and those sediments identified as most contaminated (27 stations),
- ***Segment 2*** (Lower Harbor) included the area between the Coggeshall Street Bridge and the hurricane barrier (29 stations),
- ***Segment 3*** (Outer Harbor) included the area beyond the hurricane barrier and a transition into Buzzards Bay to the edge of the Fishing Closure Area III (23 stations).

Within each of these segments, a systematic hexagonal grid consisting of approximately 30 units (stations) was applied (Figure 1). Because the area encompassed by Segments 1, 2, and 3 becomes progressively larger, the size of individual hexagons is adjusted according to the size of the segment. This means that the hexagons are approximately 0.25-mile wide in Segment 1, 0.5-mile wide in Segment 2, and over 1-mile wide in Segment 3. Theoretically, any position sampled within a hexagon would constitute a station location, but in actual practice the coordinates in the center of each hexagon were used as the original target location.

Navigation was performed using a Northstar 941X Differential Global Positioning System (DGPS). Stations were located using the target coordinates established during the 1993 and 1995 surveys. For the most part, these target locations were suitable sites for grab sampling, but there were instances where underwater hazards or sedimentary conditions precluded successful sampling and it was necessary to reposition within the station hexagon boundaries. The actual coordinates for the 79 stations sampled are provided in Appendix 1. Stations are formally designated "NB99-xxx" to

Figure 1. Map Showing Station Numbering System for New Bedford Harbor Benthic Monitoring.



designate the current sampling year, but for simplicity's sake this prefix will not be used in the remainder of this report.

Field measurements of temperature, dissolved oxygen, and salinity were taken 1 m above the bottom at each of the 79 stations using a YSI Model 6920 multiparameter water quality monitor. A stainless steel 0.04-m^2 Ted Young (modified Van Veen) grab was used to take all biology (benthic infaunal) samples and some of the chemistry/toxicity samples. The majority of the chemistry/toxicity samples were taken with a larger 0.1-m^2 Ted Young grab. Both grabs were coated with Kynar, a Teflon-like substance intended to protect the chemistry samples from contamination from the grab itself. Three replicate grabs were taken for benthic biology at each station and a variable number of grabs were taken in order to obtain sufficient sediment for the chemistry/toxicity samples.

Benthic biology samples were checked for depth of penetration (7 cm was considered acceptable), depth of the apparent redox potential depth (RPD), and sediment color and texture. A rough description of the appearance of the sediment was included in the field notes. After removal of a 2.5-cm core for sediment grain-size analysis, the samples were washed into a bucket, sieved through a 500-μm screen, and fixed in 10% buffered formalin. These samples were later resieved, rinsed with freshwater, and preserved in 80% ethanol. The grain-size core was extruded into a pre-labeled WhirlPac and stored on ice.

Sediment chemistry/toxicity samples were inspected for an undisturbed surface and acceptable penetration depth. Small syringes were inserted into the sediment for extraction of sediment for acid volatile sulfide (AVS) levels. AVS samples were placed in a 2-oz jar that was filled to the top and placed on ice. The top 2–4 cm of sediment was then removed from the grab with a stainless steel spoon or scoop and placed in a large stainless steel pan with a lid. Grab sampling continued until approximately 4 L of sediment had been accumulated. The composited sediment was then stirred with the spoon until it was smooth and large clumps were gone. Sediment subsamples were removed and placed in a 4-oz jar for metals and total organic carbon (TOC) analyses and a 16-oz jar for PCB analysis. Another subsample was removed and put in a WhirlPac for grain-size analysis. The remaining sediment was put into a 1-gal polyethylene container for use in toxicity testing. All samples were packed in ice.

At the end of each day, the benthic biology samples were transferred to an on-site field laboratory that was provided to ENSR for this project by the USACE. The facility is located at the USACE Project Site on Sawyer Street in New Bedford. Samples were held in formalin for no more than 48 hr after collection, at which time they were transferred to 80% ethanol. A technician, who was stationed at the facility for the majority of the time the field team was sampling in the harbor, decanted the formalin from the sample through a 500-μm sieve. The waste formalin was treated as hazardous waste and disposed into the on-site waste treatment facility at the USACE Project Site on Sawyer Street. The benthic samples were resieved with fresh water to remove salt and then preserved in 80% ethanol.

The on-site technician provided a variety of services to the project, including printing out and organizing the field data sheets, transferring the benthic samples from formalin to alcohol, preparing chain-of-custody forms, arranging for pickups of chemistry and toxicity samples by the analytical laboratories, and assisting in the transfer of grain-size and benthic biology samples to the analytical laboratories. In addition, the technician organized the field datasheets that accumulated and began the process of developing the electronic database.

Field data, including measurements taken, station location coordinates, and sample collection information, were transcribed directly into the field logbook and onto field datasheets. The format of the datasheets was based on those used during the 1993 and 1995 surveys. Electronic files of these sheets were provided by the EPA and printed by ENSR in the field laboratory. If errors were made, results were legibly crossed out, initialed and dated by the person recording the data. Corrections were written in a space adjacent to the original (erroneous) entry. Field data were reviewed by the Chief Scientist, Mr. Don Boyé, to ensure that records were complete, accurate, and legible. At the same time, the Chief Scientist verified that the instruments were calibrated and operated in accordance with the procedures specified in the QAPP. Any deviation from these procedures were reported to the Project Manager, Dr. James Blake, and discussed with Ms. McGrath the QA Officer. Data were entered from the field records into the database in order to establish electronic versions of the field hard copies. These were reviewed and approved by the Chief Scientist and QA Officer prior to release.

2.3 Laboratory Methods

2.3.1 Chemical Analyses

Table 1 summarizes the analytical methods used. PCB analysis was performed by Arthur D. Little, Inc. in Cambridge, Massachusetts. The EPA Environmental Research Laboratory Narragansett (ERLN), Standard Operating Procedure (SOP) *The Extraction of New Bedford Harbor Sediment Samples for PCBs* was used for this study, with modifications as stated in the QAPP (ENSR, 1999). The methods used to generate PCB data were specified by EPA/AED and are consistent with historical efforts to ensure data comparability. The 18 NOAA congeners were quantified using GC/ECD instrumentation.

Analyses of metals, TOC, and AVS were performed by Woods Hole Group in Raynham, Massachusetts. Extraction of metals samples was conducted using the ERLN SOP *Ultrasonic Extraction of Metals from Sediment Samples*, as modified in the QAPP (ENSR, 1999). The ERLN SOP for total digestion of sediment samples was not used, per discussions with EPA/AED. The methods for analyzing metals specified by EPA attack organic matter and remove contaminants from particle surfaces but do not completely dissolve the sediment matrix. For this reason, the resulting data do not represent "total" concentration values but rather represent the maximum bioavailable fraction.

Table 1. Laboratory Methods Used for Chemical Analyses of Samples Collected for the 1999 New Bedford Harbor LTM III Survey.

Analyte Group[1]	Laboratory SOP No.	Equivalent EPA Method No.[2]
PCBs	ADL-2819 (extraction)[3] ADL-2818 (analysis)	SW-846 3550A/3610/3660/3665 (EPA, 1986) SW-846 8082, modified (EPA, 1986)
Metals (Cu, Cr, Pb, Ni, Zn)	NA (digestion) WHG SOP 6010B ICP (analysis)	ERLN SOP *Ultrasonic Extraction of Metals from Sediment Samples* (see QAPP, Section 7.2.1 for modifications) SW-846 6010B (EPA, 1986)
Metals (As, Cd, Se)	NA (digestion) WHG SOP 6020 ICP-MS (analysis)	ERLN SOP *Ultrasonic Extraction of Metals from Sediment Samples* (see QAPP, Section 7.2.1 for modifications) SW-846 6020 (EPA, 1986)
Mercury	WHG SOP 7471 (preparation and analysis)	SW-846 7471A (EPA, 1986)
TOC	WHG SOP TOC 9060 Mod. for Soil/Sediment (preparation and analysis)	SW-846 9060, modified (EPA, 1986)
Percent Solids	NA	SM 2540G (APHA-AWWA-WPCF, 1992)
AVS	WHG SOP AVSSEM (preparation and analysis)	Boothman and Helmstetter, 1992

[1]See QAPP Section 1 for the compounds in each analyte group.
[2]References: see QAPP Section 15.
[3]Based on the ERLN SOP *The Extraction of New Bedford Harbor Sediment Samples for PCBs.* See QAPP for modifications.
NA indicates that the EPA method was used; ADL is Arthur D. Little, Inc; WHG is the Woods Hole Group.

One common model used to assess bioavailable metals in anoxic sediments is to examine sulfide (FeS) mineralogy (an effective metal-binding mineral) with respect to simultaneously extracted metals (Di Toro et al. 1992). The approach taken to assess this parameter measures AVS and simultaneously extracted metals. AVS measurements were within the scope of this project; however, simultaneously extracted metals were not.

2.3.2 Physical Analyses

Grain size analysis was performed by Geo/Plan Associates in Hingham, Massachusetts. Sediment grain-size was determined for sands using wet sieve analysis (NOAA, 1993) and for silt and clay using pipette analysis (NOAA, 1993; Head, 1992). Wet sieving yields percentages of the following phi-classes: gravel (>2.00 mm), very coarse sand (1.00-2.00 mm), coarse sand (0.50-1.00 mm), medium sand (0.25-0.50 mm), fine sand (0.125-0.25 mm), very fine sand (0.0625-0.125 mm), and silt-and-clay (<0.0625 mm). Pipette analysis results in percentages of silt (0.0039-0.0625 mm) and clay (<0.0039 mm).

2.3.3 Toxicity Testing

Ten-day acute exposure solid phase (sediment) toxicity tests with the amphipod *Ampelisca abdita* were performed by EnviroSystems, Inc. (ESI) in Hampton, New Hampshire. After log-in, toxicity sediment samples were placed in a secure refrigerator and stored at a temperature of 2-4°C until test initiation.

Control sediment used in the amphipod toxicity testing program was provided by EPA ERLN. The control sediment (designated CLIS Ref) was collected at the reference site for the Central Long Island Sound (CLIS) Disposal Site. Control sediment samples were received at ESI on September 16, October 11, and October 20, 1999. No written documentation was provided with the samples; however, ERLN staff verbally confirmed that sediment was collected from the Reference Area adjacent to the CLIS dredge spoil disposal site and that sediments had been pressure-sieved using a 2-mm mesh. Three gallons of sediment arrived in polyethylene jars and two gallons of sediment arrived in glass jars. Overlying water used in the testing was natural seawater collected by ESI from the Hampton/Seabrook Estuary. This water is classified as SA-1 and has been used to culture and test marine test organisms since 1991.

The testing was conducted in six series with a total of 79 New Bedford Harbor sediments during October to December 1999 (Table 2).

Table 2. New Bedford Harbor Sediment Collection and Test Series Dates.

Bioassay Number	Dates Collected	Date Test Started	Sediment Sample (Station) Numbers
1	09/15–20/99	10/08/99	235, 236, 240, 241, 242, 245, 247, 249, 250, 304, 305, 310, 311, 331, 349, 352
2	09/21–24/99	10/09/99	204, 207, 208, 211, 212, 216, 217, 220, 222, 224, 225, 226, 227, 230, 231, 253
3	09/24–29/99	10/24/99	123, 125, 126, 128, 131, 139, 147, 150, 151, 152, 154, 155, 221, 237
4	10/01–10/99	10/26/99	105, 111, 114, 115, 130, 134, 135, 138, 140, 146, 318, 325, 335, 339, 341
5	10/06–08/99	10/29/99	108, 109, 202, 309, 317, 323, 324, 332, 333, 334, 338, 340, 345, 346
6	10/27–11/18/99	11/23/99	117, 120, 121, 218

The testing protocol was based on methods and procedures presented in *Standard Operating Procedure for Conducting Acute Toxicity Testing using Ampelisca abdita* (EPA, 1990), *Laboratory Method Manual - Estuaries Volume 1: Biological and Physical Analyses* (EPA, 1993), and *Methods for Assessing the Toxicity of Sediment-associated Contaminants with Estuarine and Marine Amphipods* (EPA, 1994). Details of the protocols are included in the QAPP (ENSR, 1999), but in general were as follows:

- Assays were conducted using a static renewal test mode using five (5) replicates per treatment with 20 organisms per replicate.
- Test temperatures were 20±1°C and a salinity of 30 ±2ppt.
- Temperature, salinity, dissolved oxygen, and pH were monitored daily.
- Control sediment was from central Long Island Sound.
- Control survival was equal to or greater than 90%.

Several deviations from the study-specific protocol occurred during the testing program. These included slight exceedence of sample storage temperature criteria in the sediment sample storage refrigerator, deviations in *Ampelisca* holding circumstances, and deviations in temperature and dissolved oxygen levels during testing periods. The nature of the deviations were considered minor and it was the opinion of the ESI Study Director (Ms. Natalie Harris) that they had no impact on the outcome of the test. ENSR concurred in this opinion and is not aware of any additional circumstances of factors that may have affected the integrity of these studies.

Individual reports containing results on each of the test series from the New Bedford Harbor whole sediment testing program were provided by ESI and submitted to USACE and EPA in March 2000. These reports contain summarized test results and statistical comparisons.

2.3.4 Benthic Biology Analysis

Sorting, enumeration, and identification of the animals contained in the benthic biology samples was performed by Normandeau Associates in Bedford, New Hampshire, and by the ENSR Marine & Coastal Center in Woods Hole, Massachusetts. Sample processing generally followed protocols described in *EMAP Near-Coastal Laboratory Procedures Macrobenthic Community Assessment* (EPA, 1991), with the exception that biomass determinations were not made. All organisms were removed from the sediment residue and identified to the lowest possible taxon, usually species. Both laboratories exchanged information and specimens as part of an intercalibration exercise intended to ensure comparable identifications by both laboratories and to provide the most taxonomically correct species list possible.

3.0 RESULTS

3.1 Water Quality

The water quality data taken by CTD casts 1 m above each station sampled in the 1999 NBH program are given in Appendix 2.

3.2 Sediment Characterization

3.2.1 Grain Size

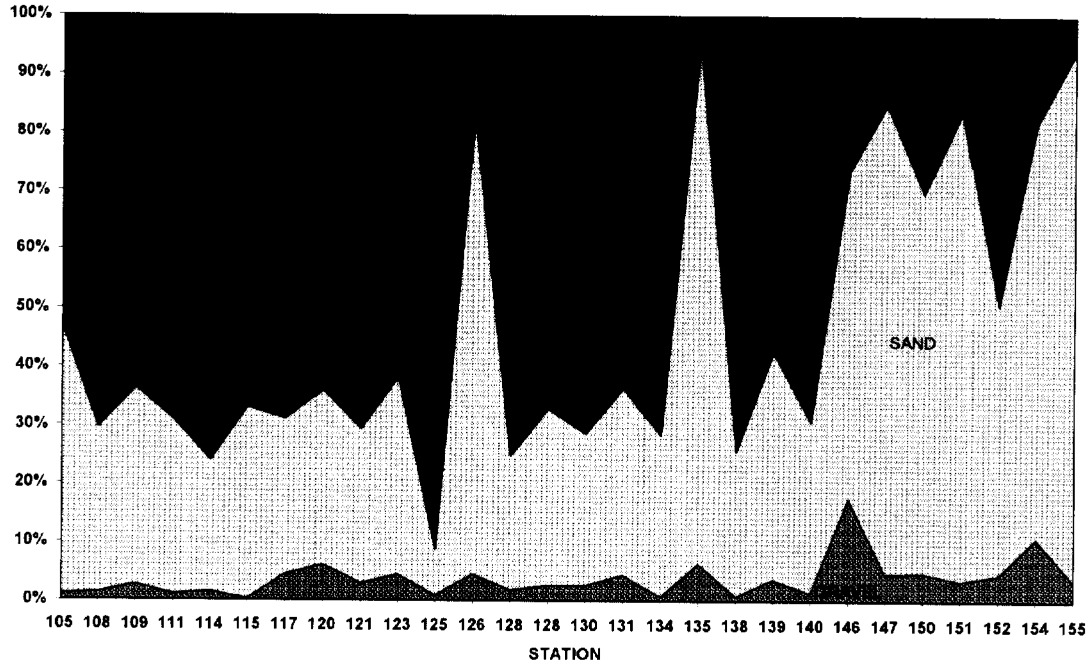
Sediment grain size composition was measured for four to six replicate samples at each station in each of the three segments of NBH. Details of these analyses are presented in Appendix 3; mean values of percent gravel, sand, and silt+clay are shown in Figures 2 and 3. Sediments in Segment 1, the Upper Harbor, had the highest percentages of silt+clay, and Segment 3, the Outer Harbor, had the lowest percentages of this size class. There was a general trend towards coarser sediments from the Upper through the Lower and into the Outer Harbor areas.

3.2.2 Total Organic Carbon

The total organic carbon (TOC) found in the sediments generally paralleled the trend of percent silt+clay: TOC was typically highest at stations where the silt+clay was also highest (Figures 4 and 5). In Segment 1 (Upper Harbor), the highest average values of TOC were 10.0, 10.1, and 10.0 % at Stations 108, 114, and 138, respectively; at these same stations, the percent silt+clay was 70.5, 76.0, and 74.4, respectively. The majority (15 of 27 replicates) of values ranged from 6.1 to 8.5, and were found primarily at stations in the central portion of Segment 1. Stations at the southern end of this segment (Stations 140–155) had the lowest TOC values of 0.52–5.5%. TOC values found at stations in Segment 2 (Lower Harbor) ranged from a high of 9.2% at Station 231 to a low of 0.16 at Station 202. The majority (17 of 30 replicates) of values ranged from 3.0 to 5.5%, and were found scattered throughout the segment, with no apparent north-to-south trend as seen in Segment 1. The lowest TOC values measured were found in Segment 3 (Outer Harbor); values ranged from a low of 0.04% at Station 306 to a high of 3.3% at neighboring Station 309. Nine of the 23 stations had TOC values of less than 1%; these stations were found throughout the segment, with no apparent north-to-south trend. Appendix 4 includes the sediment TOC data developed for samples taken in NBH in 1999.

Figure 2. Sediment Composition: Top, Upper Harbor; Bottom, Lower Harbor.

NBH Segment 1 Ave. Sediment Composition



NBH Segment 2 Ave. Sediment Composition

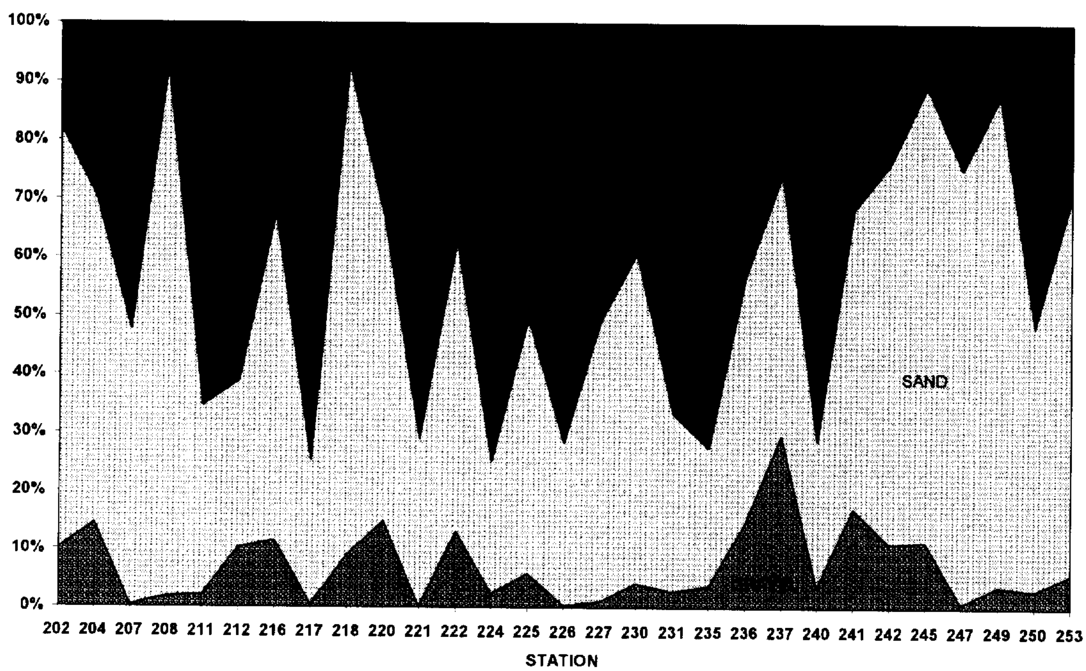


Figure 3. Sediment Composition: Outer Harbor.

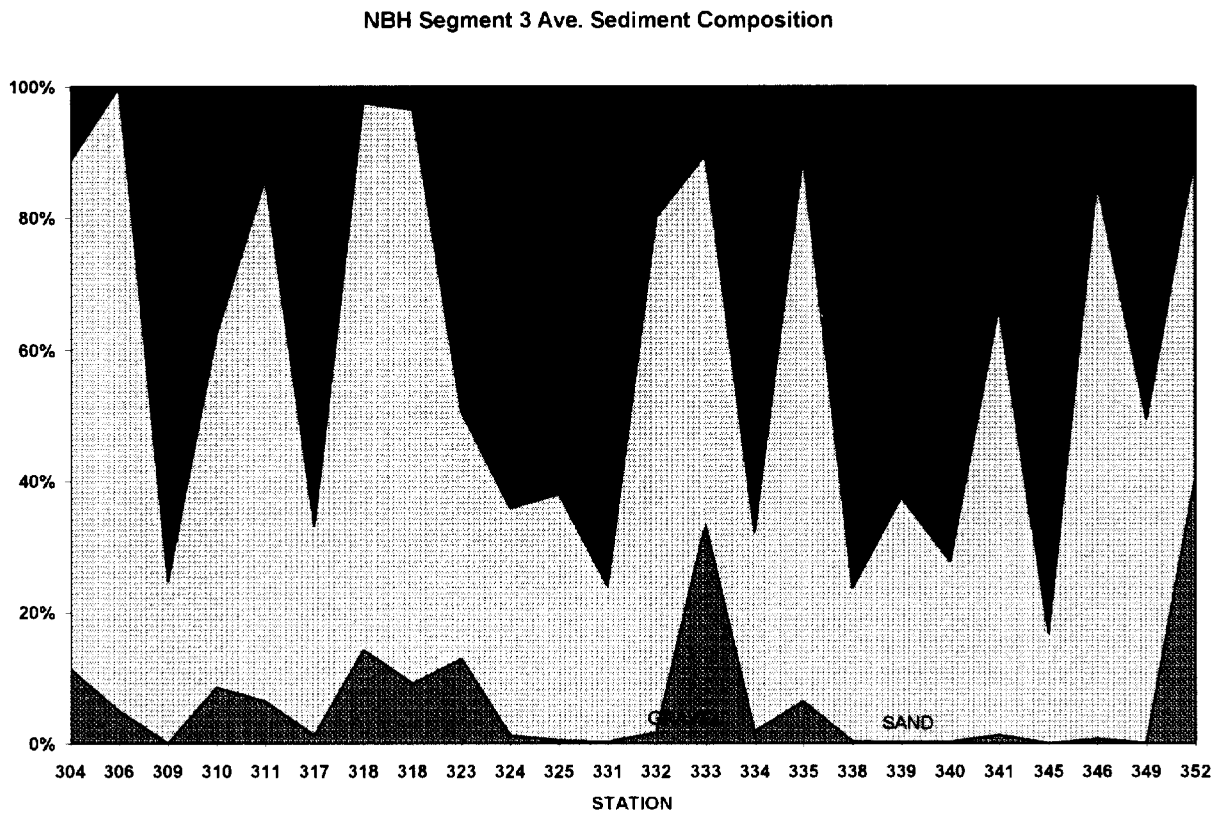
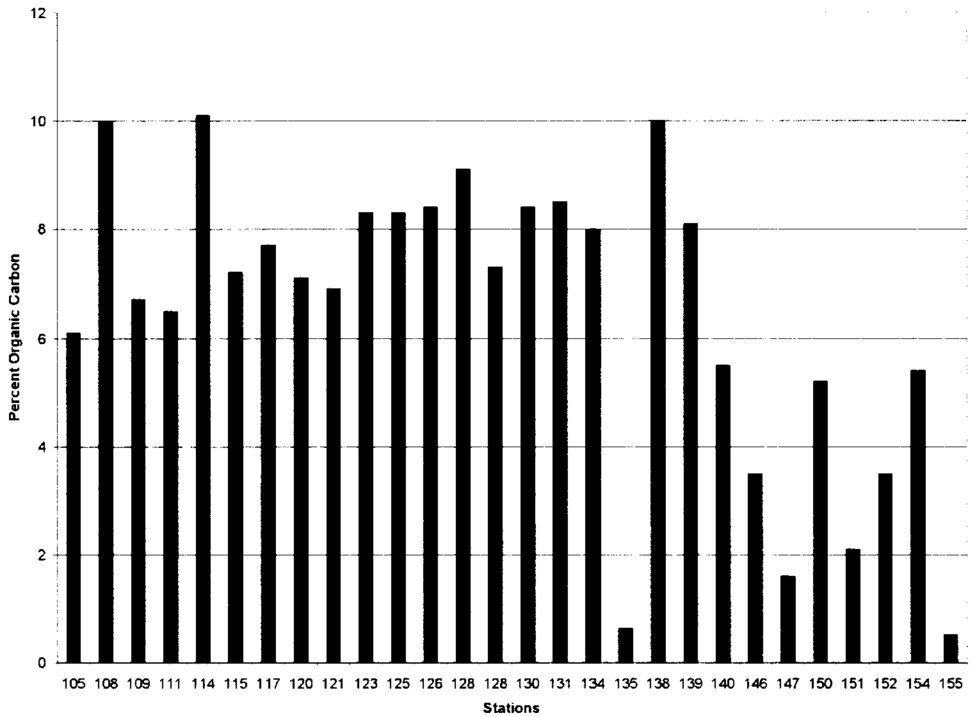


Figure 4. Total Organic Carbon: Top, Upper Harbor; Bottom, Lower Harbor.



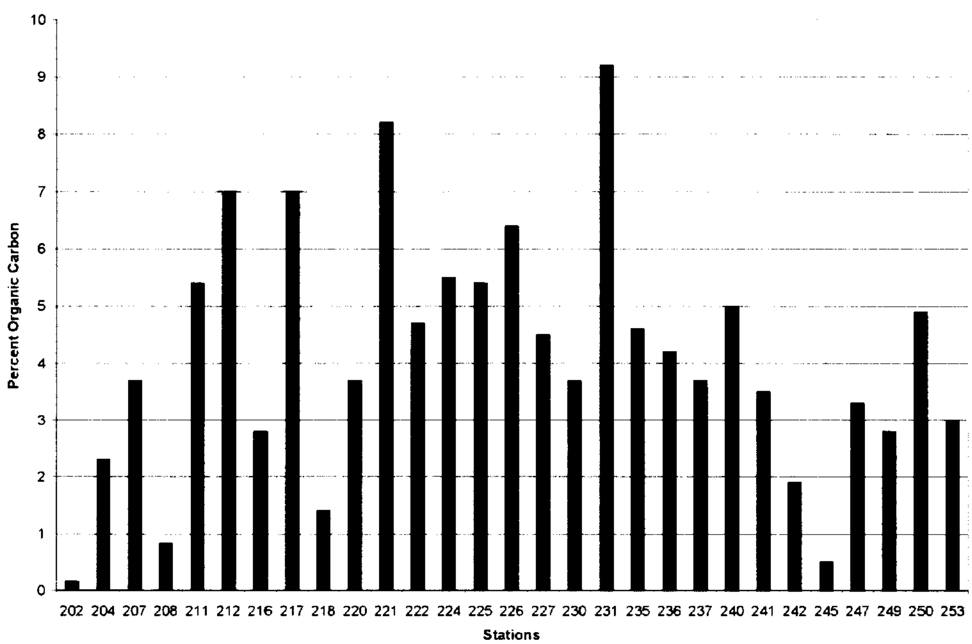
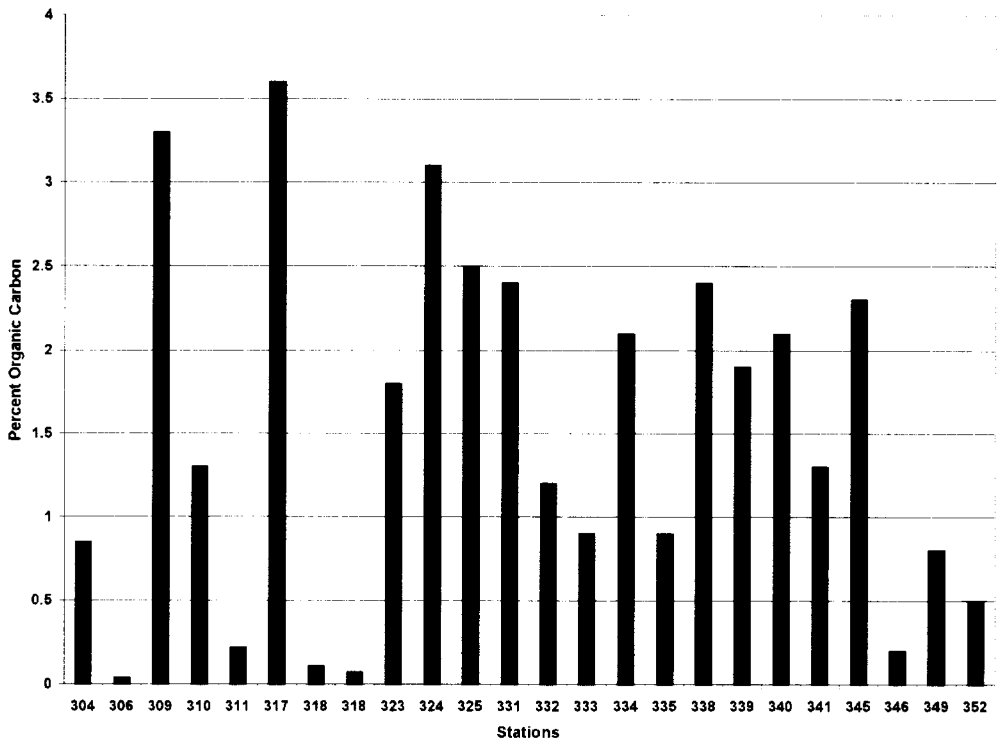


Figure 5. Total Organic Carbon Concentration for Outer Harbor Stations.



3.3 Contaminant Chemistry

3.3.1 PCBs

Figures 6 and 7 summarize the data obtained from the 1999 field collection effort. Only the 18 NOAA congeners have been measured in the program and these figures summarize the total of the 18 congeners for consistency with the previous two LTM reports. Readers are advised that the summations depicted in these figures and in Appendix 5 are not equivalent to total arochlor or homologue PCB's.

As depicted in both figures, total PCB concentrations (as the sum of the 18 NOAA congeners) in the Upper, Lower, and Outer Harbor areas differ dramatically. Concentrations at one-third of the stations in the Upper Harbor were greater than 100 ug/g. Concentrations at Upper Harbor stations are one order of magnitude higher than those encountered at stations in the Lower Harbor, and two orders of magnitude higher than those at stations in the Outer Harbor. In the Lower Harbor sediments, the sum of these 18 NOAA congeners were within the 2–20 ug/g concentration range, and those at the majority of stations in the Outer Harbor were less than 1 ug/g. Appendix 5 includes the details of the total PCBs and the individual 18 NOAA congeners found in the NBH 1999 samples.

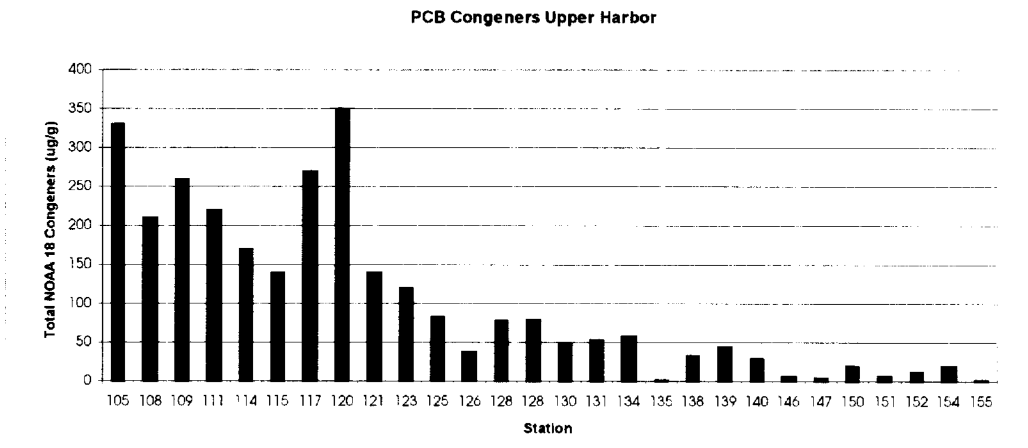
3.3.2 Metals

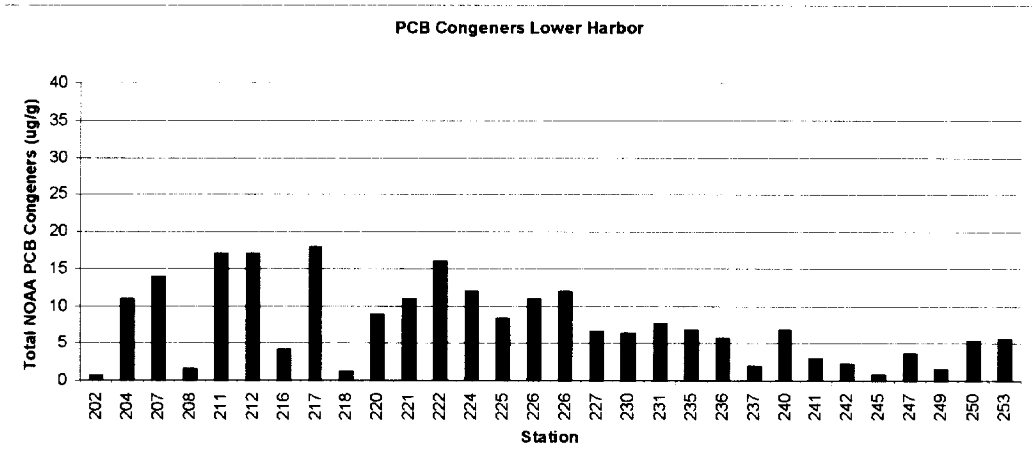
Of the metal parameters measured in the program, cadmium (Figure 8), copper (Figures 9 and 10), and lead were the most elevated above background levels (data are presented in Appendix 6). Sediment-bound cadmium concentrations ranged from 5 to 20 ug/g in the Upper Harbor, 1–5 ug/g at stations in the Lower Harbor, and 1 ug/g or less in the Outer Harbor as summarized in Figure 8. Copper concentrations were relatively high—in the range of 100 to 1,000 ug/g—in both the Upper and Lower Harbor areas (Figures 9 and 10). The highest copper concentration measured in the program was at Station 207 (5,060 ug/g) in the Lower Harbor. Copper at this single station was higher by a factor of 3–4 than at any other station. Concentrations at stations in the Outer Harbor generally ranged from 2–60 ug/g, and are probably not much different from background concentrations as estimated from global mean sediment values (Bowen, 1979). Sedimentary lead concentrations were typically 200–500 ug/g in the Upper Harbor, 100–300 ug/g in the Lower Harbor, and with few exceptions, less than 30 ug/g in the Outer Harbor (Figure 11).

3.3.3 Acid Volatile Sulfides

Detailed results of this analysis are in Appendix 7. Metal-binding sulfide concentrations diminished from Upper and Lower Harbor stations to those in the Outer Harbor. However, simultaneously extracted metals were not measured as part of this project; therefore metal bioavailability assessments cannot be made.

Figure 6. Total PCB's as the Sum of NOAA 18 Congeners at New Bedford's Upper, Lower, and Outer Harbors. 0-4 cm Sediment Surface.





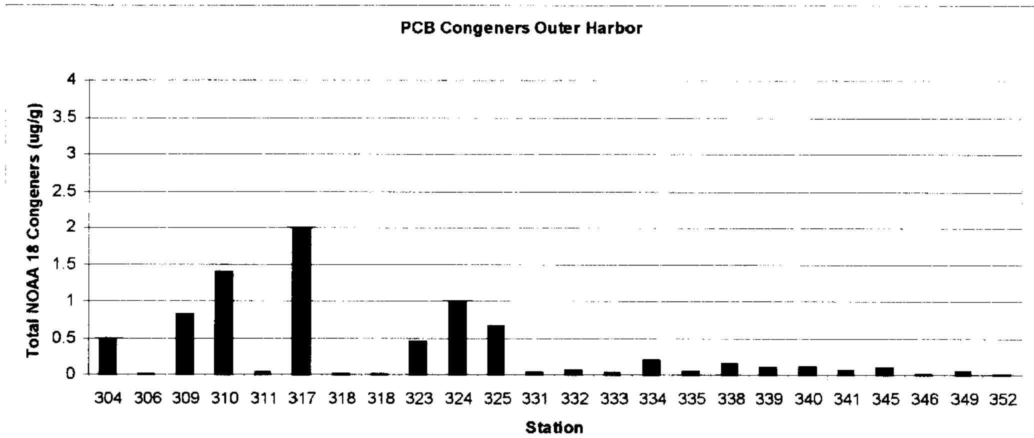


Figure 7. Map Showing Concentrations of PCBs in New Bedford Harbor in 1999.

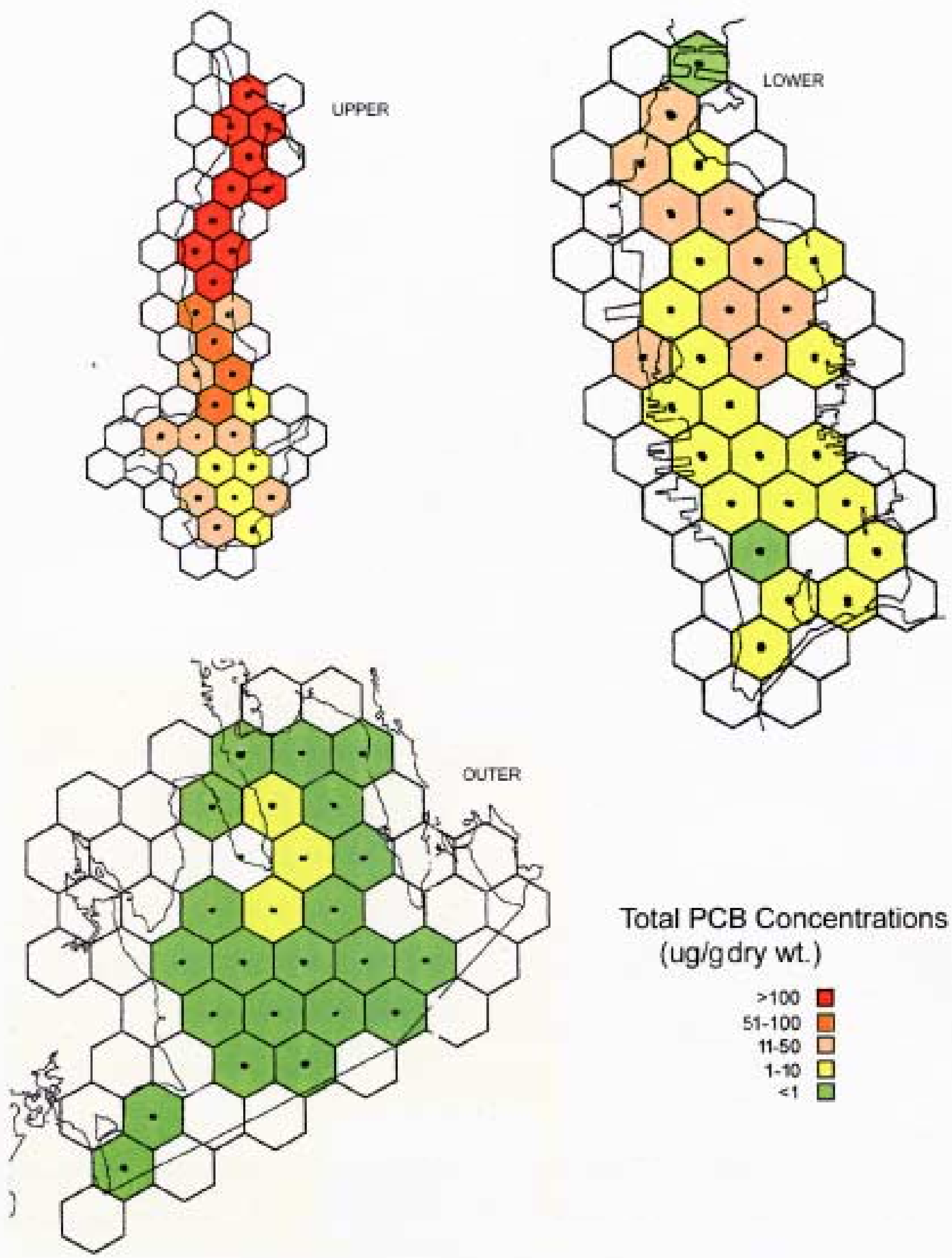


Figure 8. Cadmium Concentrations at New Bedford's Upper, Lower, and Outer Harbors. 0-4 cm Sediment Surface.

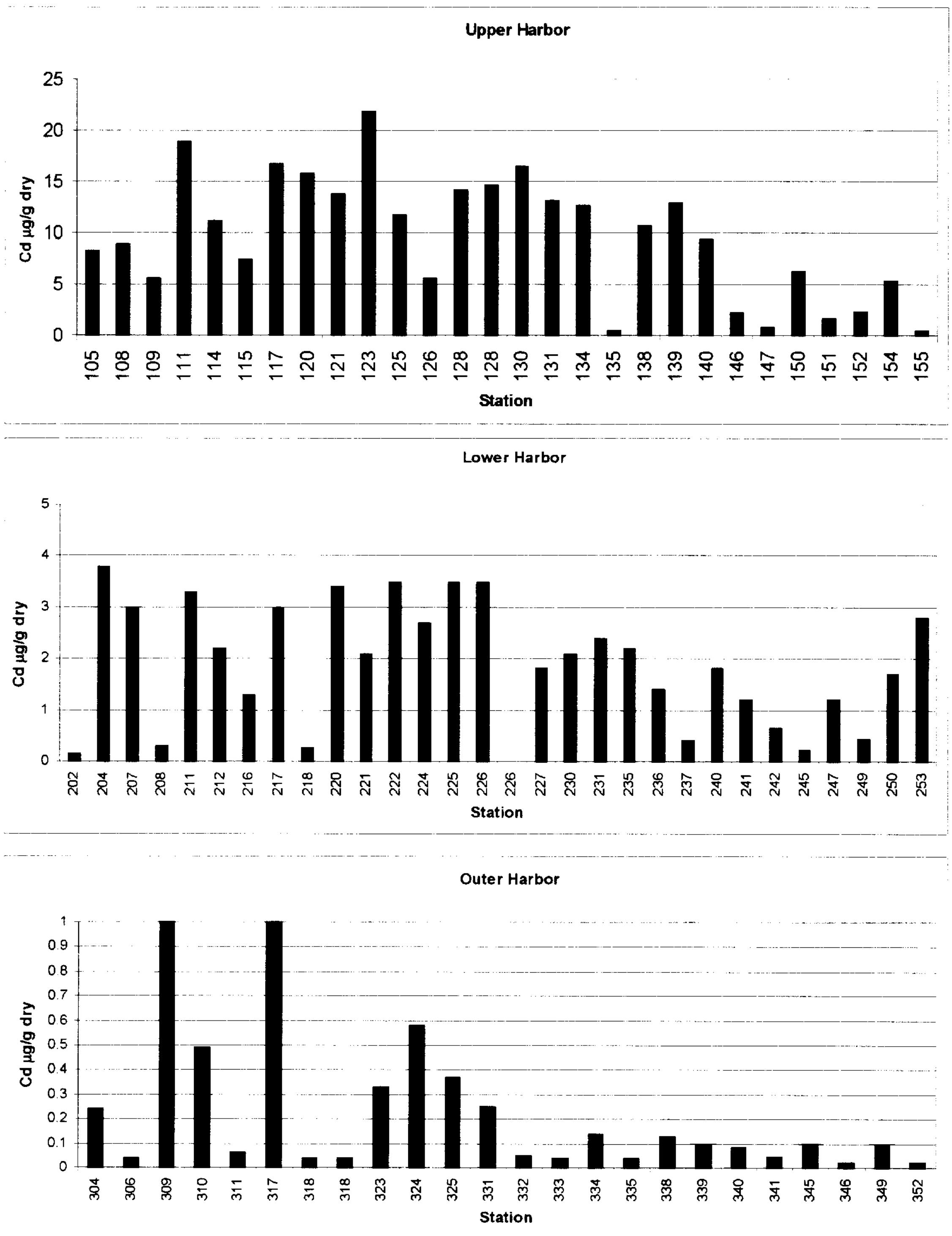


Figure 9. Copper Concentrations at New Bedford's Upper, Lower, and Outer Harbors. 0-4 cm Sediment Surface.

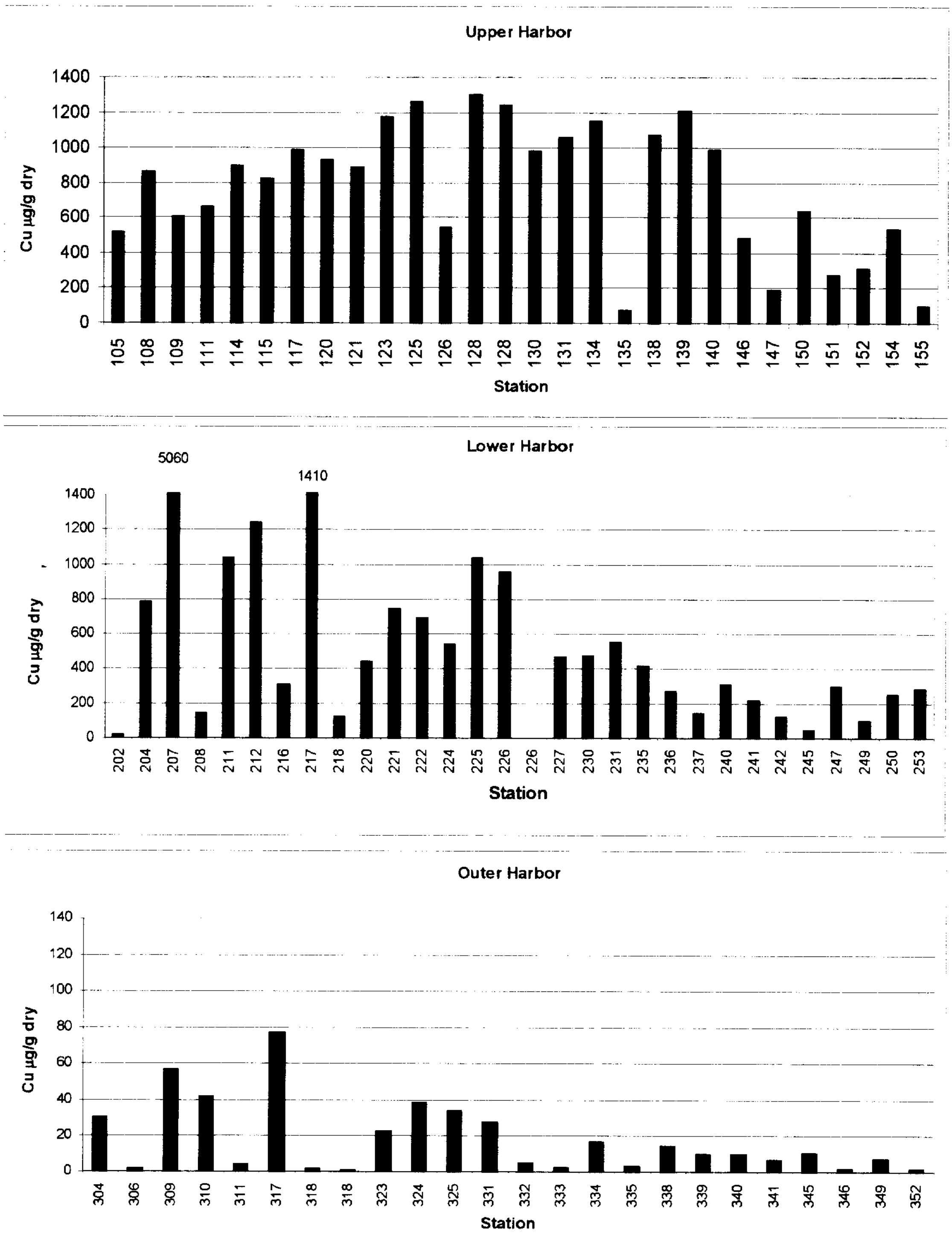


Figure 10. Map Showing Concentrations of Copper in New Bedford Harbor Sediments in 1999.

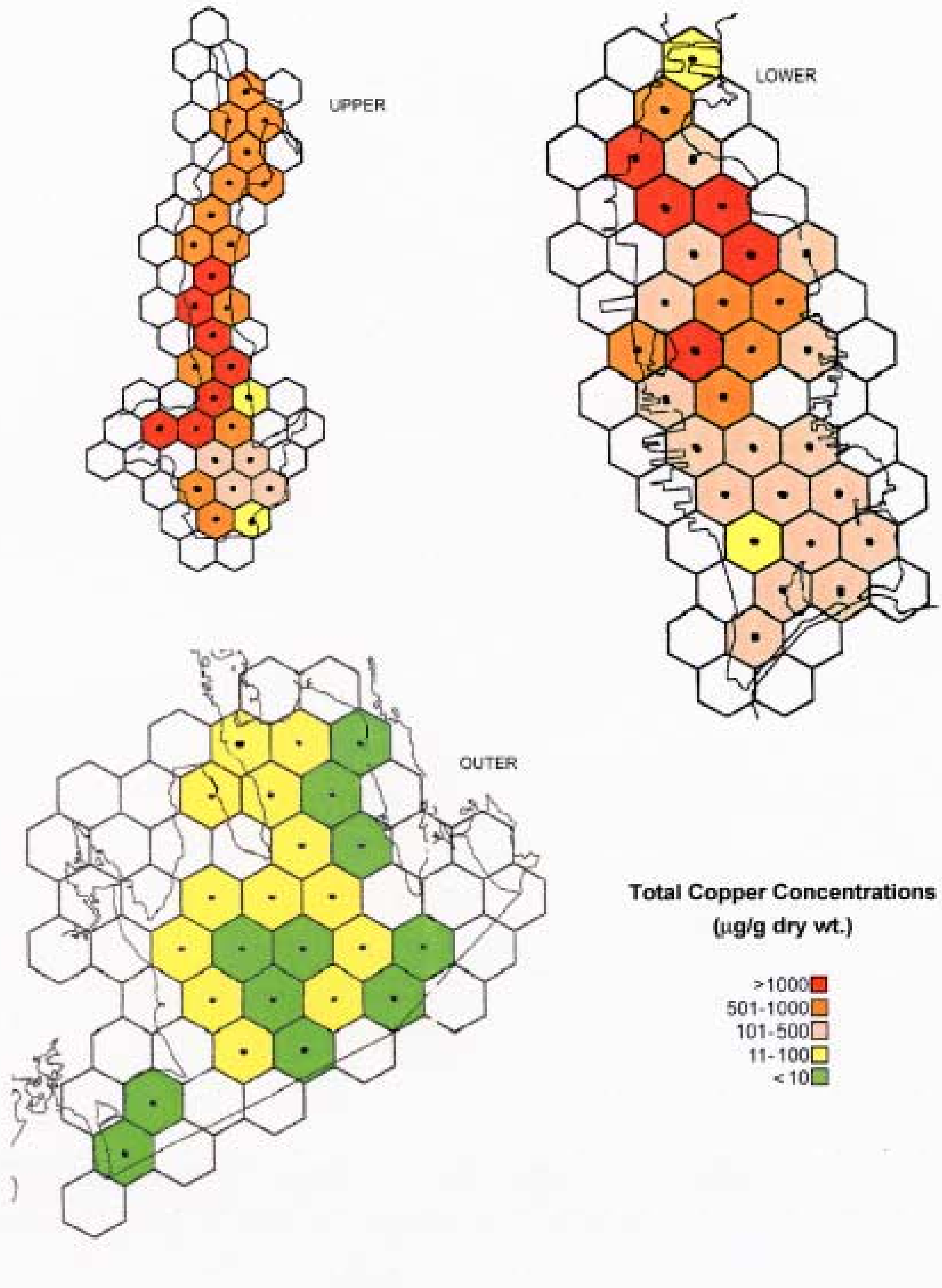
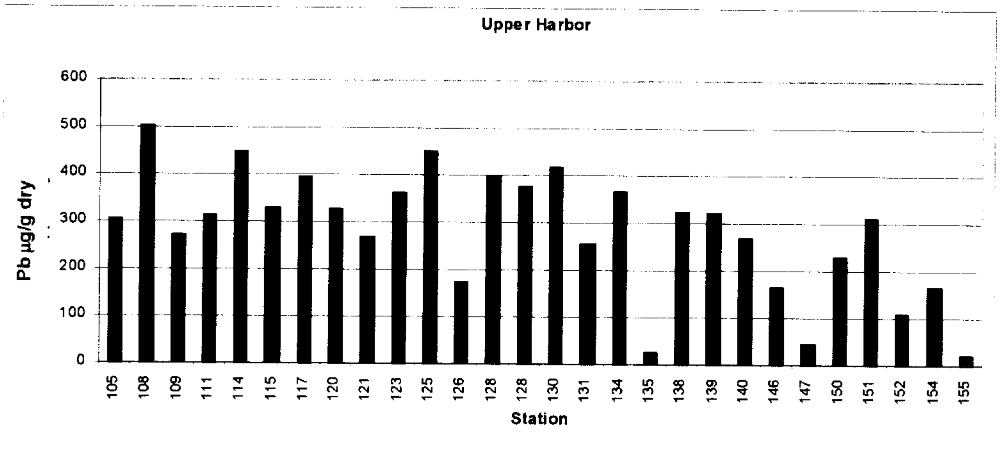
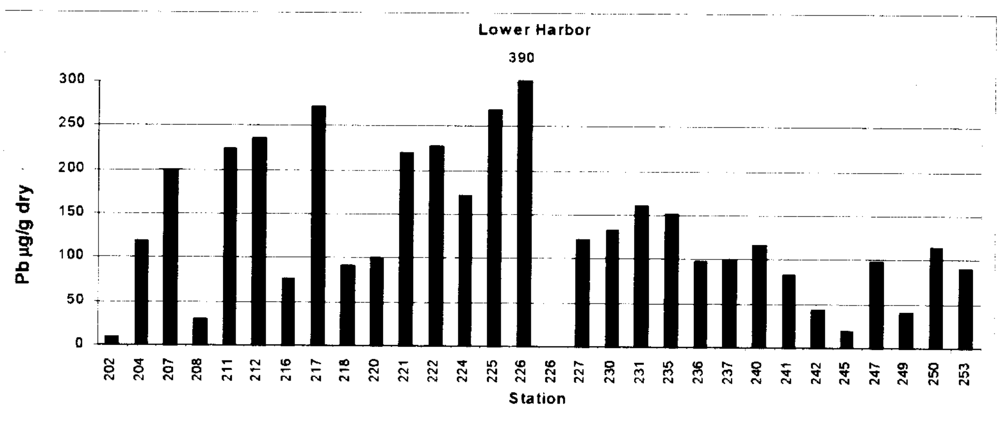
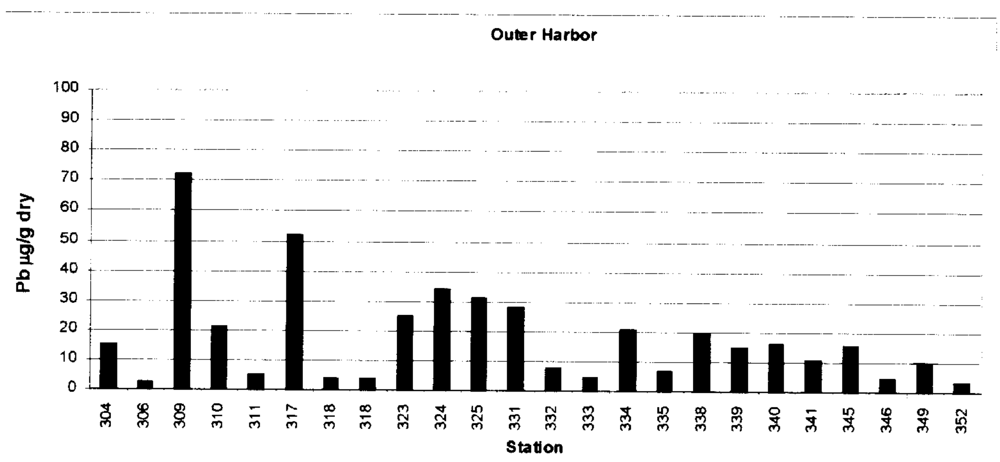


Figure 11. Lead Concentrations at New Bedford's Upper, Lower, and Outer Harbors. 0-4 cm Sediment Surface.







3.3.4 Sediment Toxicity

The amphipod 10-day survival responses for the entire NBH baseline evaluation are summarized in Appendix 8. Survival of organisms exposed to the NBH test sediment samples ranged from 0 to 90%. When normalized to the CLIS reference sample, amphipod survival was statistically significantly lower for 68 of the 79 sediments tested. The results showed strong spatial patterns; therefore, the discussion of the results has been organized according to NBH Segments 1 (Upper Harbor), 2 (Lower Harbor), and 3 (Outer Harbor).

3.3.5 Segment 1 (Upper Harbor)

Amphipod survival was assessed using 10-day whole sediment toxicity tests for 27 test sediments (Stations 105 to 155) located in NBH Segment 1 (Upper Harbor). On the whole, these sediments were extremely toxic, with 23 of the 27 sediments tested resulting in complete mortality (i.e., 0% survival). Survival in all 27 sediment tests was statistically significantly lower than in the corresponding CLIS control sediments. For the four test sediments without complete mortality, test organism survival ranged from a high of 25% (Station 135) to 1% (Station 155). Due to the widespread mortality, it is hard to distinguish spatial patterns of toxicity among the stations in the Upper Harbor. However, it was noted that all the sediments that had survival of some exposed organisms (i.e., <100% mortality) (Stations 135, 147, 152, 155) were all located along the eastern margin of Segment 1 near the southern (seaward) end.

3.3.6 Segment 2 (Lower Harbor)

Twenty-nine stations were tested in NBH Segment 2 (Lower Harbor). Mean amphipod survival for test sediments was very variable in this segment, ranging from 0 to 78%. Amphipod survival in all 29 sediment tests was statistically significantly lower than in the CLIS control sediments. Ten of the test sediments had organism survival below 25%, and, of these, three sediments (Stations 204, 207, 230) resulted in 100% mortality. Ten sediments had organism survival between 25 and 50%, seven (duplicates from Station 226 were averaged) were from 50 to 60%, and only two sediments had greater than 60% survival (Figure 12). Examination of the spatial pattern of toxicity results indicates that the most toxic sediments were located in the northern half of this segment and toxicity decreases southward. Some exceptions to this pattern were Stations 202, 222, 226, and 231, which were less toxic than would be expected based on their location. The reasons for this decreased toxicity are not known, but scour/erosional effects or distance offshore may be involved. For example, Station 202 is located at the constricting channel between the Upper and Lower Harbors in an area likely to be subject to high-velocity riverine and intertidal flows, and the sediment may be less depositional that at other locations. Alternatively, Stations 222, 226, and 231 are more centrally located, away from docks, wharves, and localized inputs. Additional information regarding the chemistry of the sediments should be considered to explain these differences.

3.3.7 Segment 3 (Outer Harbor)

Twenty-three stations were tested in NBH Segment 3 (Outer Harbor). Mean survival of amphipods exposed to test sediments from this segment was clearly the highest of the three harbor areas, with survival ranging from 24 to 90%. The majority of the sediments exhibited amphipod survival greater that 80% (Figure 12). Of the 23 sediment tests, survival in 12 was statistically significantly lower than in the CLIS control sediments. None of the test sediments exhibited 100% amphipod mortality. One of the test sediments had organism survival below 25% (Station 304), one was 25 to 50% (Station 310), and nine were between 50 and 80%. The spatial pattern of toxicity shows a gradient of decreasing toxicity with distance from the mouth of New Bedford Harbor (Figure 12). The four samples that demonstrated the most toxicity are among the five sediment samples at the northern end of Segment 3 (Stations 304, 306, 310, 311). Interestingly, the fifth sediment (Station 309) in the northern end had the highest organism survival (90%) of any New Bedford Harbor sediment tested. Starting with the line formed by sediment Stations 317 to 318 (see Figure 1), most of the sediments do not statistically differ from the CLIS control sediments, and those that are significantly different show minimal toxicity (e.g., 75–79% survival). Slight exceptions to this statement include Station 318 (65% survival) and Station 352 (66% survival). Overall, the results of the toxicity tests on sediments from Segment 3 indicate that the factors likely responsible for the toxicity seen in the Upper and Lower Harbors rapidly diminish with distance from these sources.

3.4 Benthic Fauna

The database generated for this project contained a number of taxa that are not considered in the following discussion. A few taxa, including epifaunal, clinging, or boring organisms such as *Crepidula*, *Mytilus*, *Crassostrea*, certain polydorid polychaetes, and caprellid amphipods, are not considered true constituents of the infaunal community, and are therefore excluded from any characterization of the community. These taxa are marked with an asterisk in the species list presented in Appendix 9. In addition, when juvenile or damaged specimens could not be identified to species, the category "spp." was used. If no species were identified in the genus to which these specimens belong, then the taxon is included in discussions of both density and diversity and is included in the species list (Appendix 9). If species were identified (and especially if more than one species was identified) in the genus, then the taxon was considered as contributing to the total density of infaunal organisms, but was not included in discussions of species richness or diversity nor in the species list (Appendix 9). Oligochaetes were not identified to species, but are an important component of the fauna and are therefore included in both density and diversity measurements. Appendix 10 contains the benthic data developed for NBH samples taken in 1999.

Figure 12. Map Showing Percent Survival of *Ampelisca abdita* in Toxicity Tests of New Bedford Harbor Sediments in 1999.

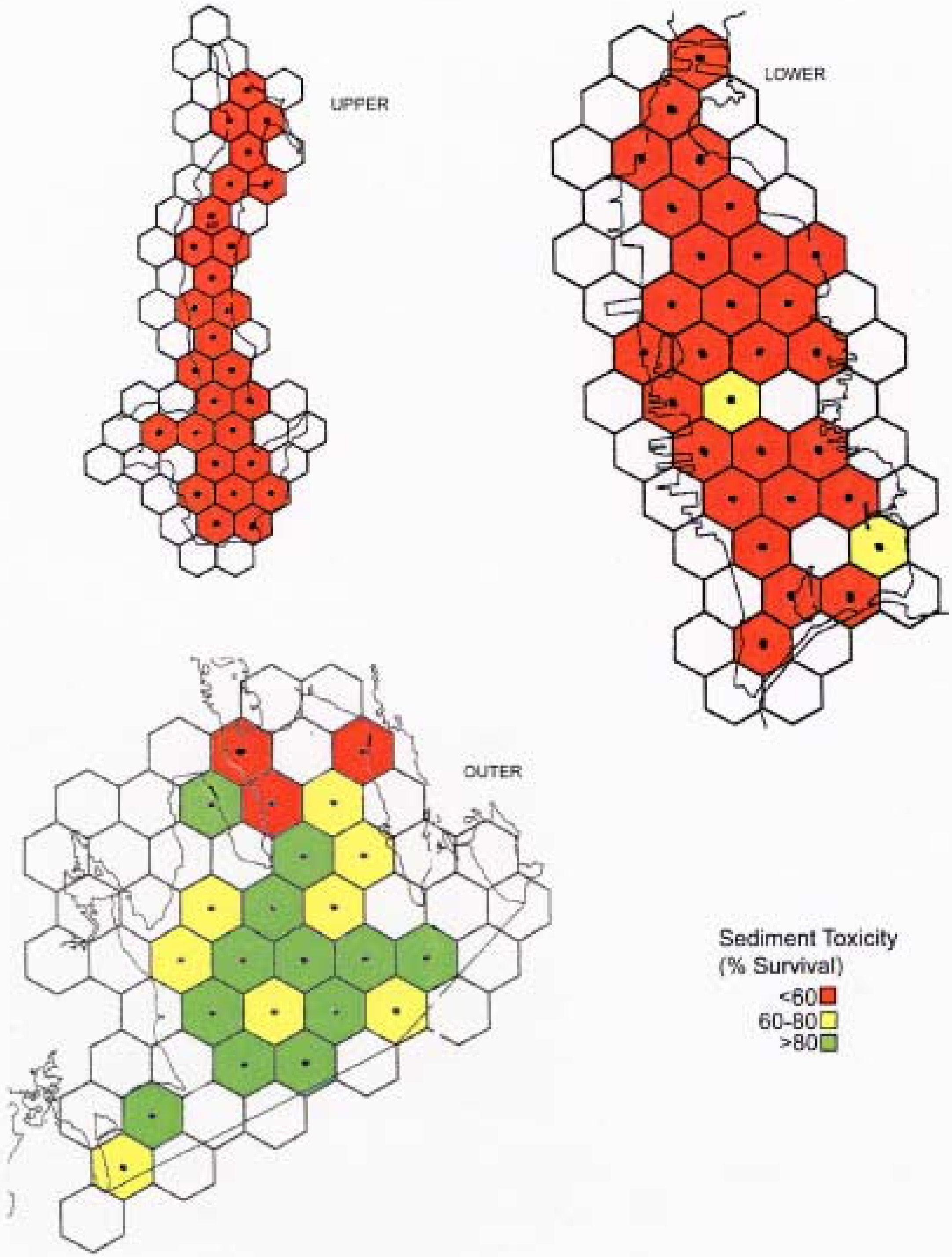


Table 3 shows the number of valid taxa and total density in each of the three areas sampled. Overall, the Lower Harbor had only 70% of the density but twice as many species as the Upper Harbor, and the Outer Harbor had approximately half the density but twice as many species as the Lower Harbor (Figure 13).

Table 3. Number of Species and Total Density in the Three Areas of New Bedford Harbor.

	Segment 1 Upper Harbor	Segment 2 Lower Harbor	Segment 3 Outer Harbor
Number of species	48	105	213
Total density	75,201	53,131	27,092

3.4.1 Segment 1 (Upper Harbor)

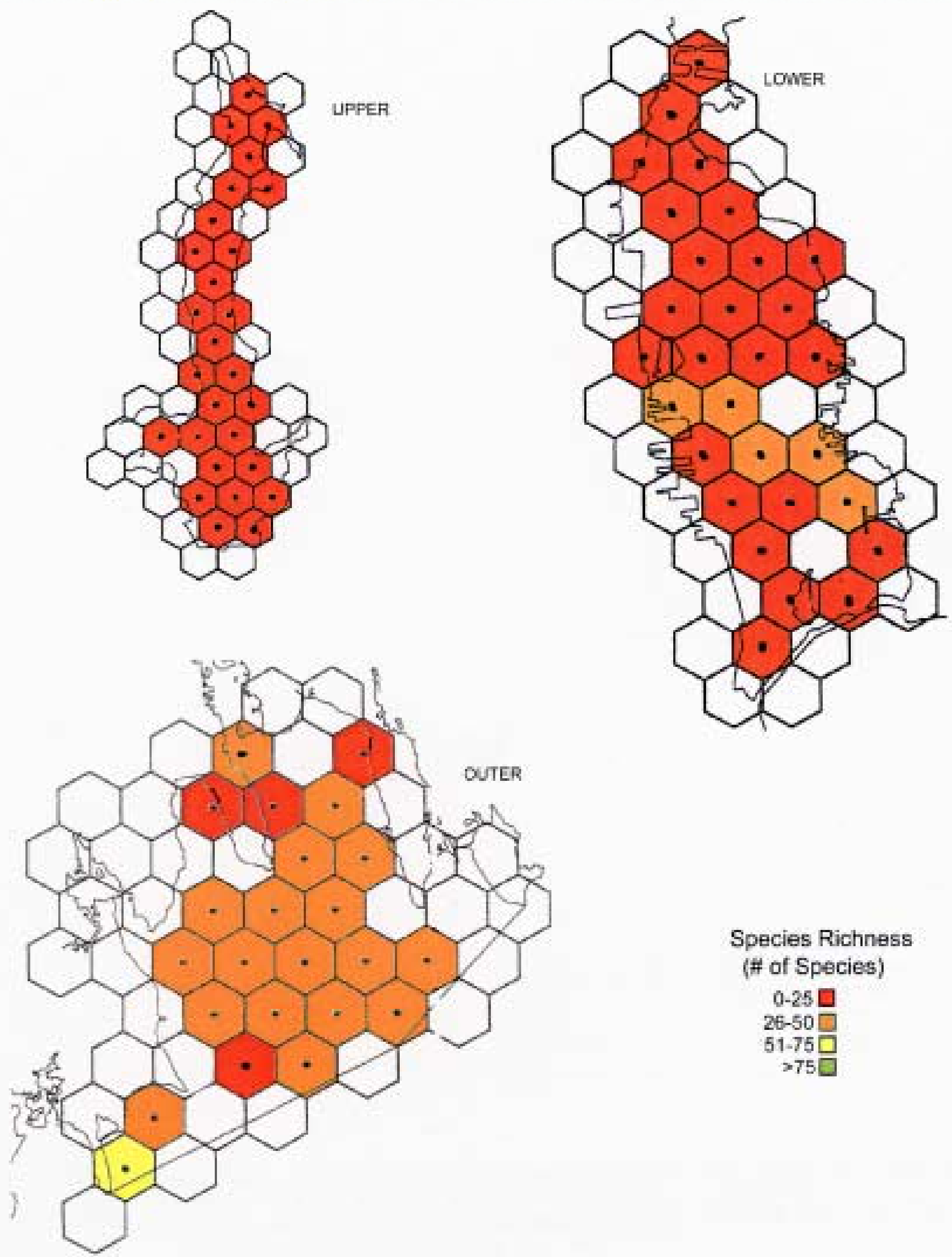
Stations in Segment 1 were characterized by low species diversity (as measured by number of taxa) and high densities, particularly of the dominant organisms. Table 4 shows the top dominant species and their total density in all Segment 1 replicates combined. Three bivalves (B), four polychaetes (P), two gastropods (G), and oligochaetes constitute the top dominants.

Table 4. Dominant Species in NBH Segment 1 (Upper Harbor).

Species	Total Density	Cum. Percent
1. *Gemma gemma* (B)	34,725	46.2
2. *Streblospio benedicti* (P)	17,670	69.7
3. *Mulinia lateralis* (B)	7,479	79.6
4. *Hydrobia truncata* (G)	6,624	88.4
5. Oligochaeta	3,003	92.4
6. *Eteone heteropoda* (P)	1,974	95.0
7. *Tharyx acutus* (P)	833	96.1
8. *Mercenaria mercenaria* (B)	444	96.7
9. *Iylannasa obsoleta* (G)	382	97.2
10. *Polydora comuta* (P)	334	97.6

The bivalve *Gemma gemma* accounted for nearly half of all organisms collected at Segment 1 stations and was most abundant at Stations 117, 120, and 121. Another bivalve, *Mulinia lateralis*, replaced *G. gemma* at the outer stations, especially Stations 123–140. The polychaete *Streblospio benedicti* occurred in every replicate, in abundances ranging from a low of 28 individuals at Station 117/3 to a high of 1496 at Station 130/1. The gastropod *Hydrobia truncata*

Figure 13. Map Showing Total Number of Species Identified from New Bedford Harbor Sediments as Part of 1999 Survey.



had a similarly patchy distribution, occurring in densities ranging from less than 10 (e.g., Stations 108, 114, 126) to 100s (e.g., Stations 105, 115) to 1000s (e.g., Station 109, 111). Oligochaetes were found in every replicate except 115/3 and both replicates from Station 152. *Eteone heteropoda*, a predatory polychaete, was found in low numbers in every replicate, except replicate 152/1 (where it did not occur.)

3.4.2 Segment 2 (Lower Harbor)

Stations in Segment 2 were characterized by intermediate species diversity (as measured by number of taxa) and intermediate densities. Table 5 shows the top dominant species and their total density in all Segment 2 replicates combined. Three bivalves (B), six polychaetes (P), and oligochaetes constitute the top dominants.

Table 5. Dominant Species in NBH Segment 2 (Lower Harbor).

Species	Total Density	Cum. Percent
1. *Mulinia lateralis* (B)	21,374	40.2
2. *Streblospio benedicti* (P)	7,932	55.1
3. *Tharyx acutus* (P)	4,999	64.5
4. *Mercenaria mercenaria* (B)	3,823	71.7
5. *Mediomastus ambiseta* (P)	3,097	81.8
6. Oligochaeta	2,278	84.7
7. *Pectinaria gouldii* (P)	1,544	86.5
8. *Leitoscoloplos robustus* (P)	983	88.1
9. *Macoma tenta* (B)	854	89.3
10. *Polydora cornuta* (P)	630	90.3

The polychaete *S. benedicti* was the second most dominant organism at Segment 2 stations as it was at Segment 1 stations, but with half the number of individuals. Another polychaete, *Polydora cornuta*, ranked tenth in both segments, but had twice the number of individuals in Segment 2 as in Segment 1. *M. lateralis* and *Tharyx acutus* occurred in substantially higher densities in Segment 2 than in Segment 1.

3.4.3 Segment 3 (Outer Harbor)

Stations in Segment 3 were characterized by the highest species diversity (as measured by number of taxa) and the lowest densities of all three Segments. Table 6 shows the top dominant species and their total density in all Segment 3 replicates combined. Three bivalves (B), four polychaetes (P), two gastropods (G), and oligochaetes constitute the top dominants.

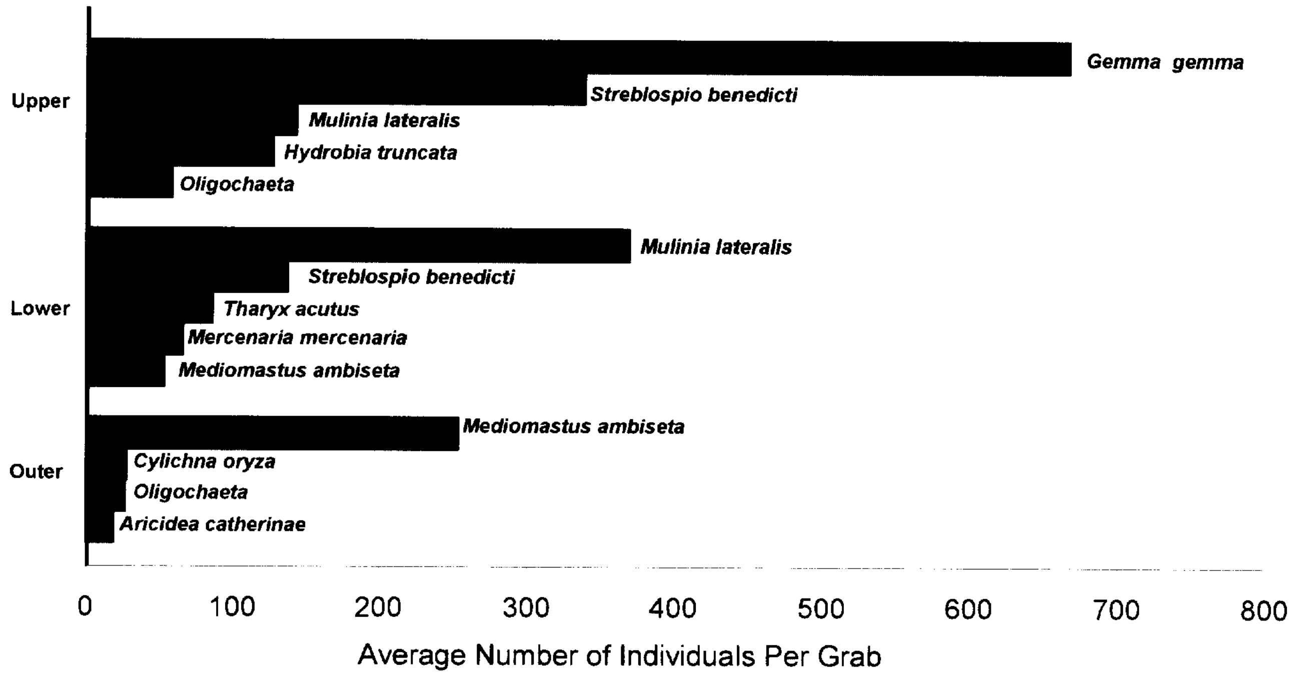
Table 6. Dominant Species in NBH Segment 3 (Outer Harbor).

Species	Total Density	Cum. Percent
1. *Mediomastus ambiseta* (P)	11,625	42.9
2. *Cylichna oryza* (G)	1,309	47.7
3. Oligochaeta	1,225	52.2
4. *Aricidea catherinae* (P)	886	55.5
5. *Nucula annulata* (B)	858	58.7
6. *Prionospio perkinsi* (P)	767	61.5
7. *Mulinia lateralis* (B)	719	64.1
8. *Polygordius* sp. A (P)	673	66.6
9. *Acteocena canaliculata* (G)	661	69.0
10. *Macoma tenta* (B)	641	71.4

Mediomastus ambiseta had a patchy distribution, sometimes occurring in numbers as high as 700–900 ind./m^2 in one replicate of a station (e.g., Stations 323, 332, 334, 341, 345) while only tens of individuals were present in the other replicate. Similarly, it was entirely absent from a few of the stations. Station 352, one of the outermost stations sampled, had an interesting fauna that included several uncommon polychaete species not routinely encountered in estuarine or coastal sampling programs.

A summary graphic shows the top 4 to 5 most abundant species in each of the Harbor segments (see Figure 14).

Figure 14. Dominant Benthic Invertebrate Species in New Bedford harbor in the 1999 Survey



4.0 DISCUSSION AND CONCLUSIONS

Although a detailed comparative analysis of the 1993, 1995, and 1999 results was beyond the scope of this 1999 summary report, we are able to provide comments on the main results. Based on the parameters measured in 1999, there is a definite trend or gradient from the upper reaches of New Bedford Harbor to the stations positioned at the outermost extent of the harbor. This gradient is characterized in Table 7, and can be seen to reflect the toxic conditions in the Upper Harbor, the mixed or intermediate conditions in the Lower Harbor, and the less toxic or cleanest conditions in the Outer Harbor. These results and trends appear to be very similar to those obtained in the previous baseline sampling.

Table 7. Comparison of Parameters Measured in NBH LTM III, Fall 1999.

Harbor Segment	Sed. Texture	% TOC	Total PCB	Metals	Toxicity	Total AVS	Faunal Densit	Species Richness	Even-ness
Upper	Finest	H	H	H	H	H	H	L	L
Lower	Mixed	I	I–L	I	H	I	I	I	I
Outer	Mixed, coarser	L	L	L	L	L	L	H	H
H = Highest, I = Intermediate, L = Lowest									

In 1993, total PCB concentrations (as the sum of the 18 NOAA congeners) ranged from a high of 431 µg/g in the Upper Harbor to a low of 0.02 µg/g in the Outer Harbor. In 1999, the highest value recorded was 350 µg/g, again in the Upper Harbor, and the lowest was 0.012 µg/g, in the Outer Harbor. Stations 108, 111, and 114 comprised the so-called "hot spot", from which heavily contaminated sediments having PCB concentrations in excess of 4000 µg/g were removed in 1994 and 1995. In 1999, those same three stations were among a group of eight adjacent stations in the Upper Harbor that had the highest PCB concentrations (Figure 7: Sta. 108: 210 µg/g; 111: 220 µg/g; 114: 170 µg/g).

Total organic carbon in the 1993 samples ranged from a high of 13% in the Upper Harbor to a low of 0.16% in the Outer Harbor; in 1999, the range was 10.1% to 0.03%, also in the same harbor areas. Thus, the highest and lowest values of these parameters were slightly lower in 1999 than in 1993, but the ranges and geographic trends were similar.

These data have not been subjected to statistical tests, but the copper concentrations encountered appear to have increased in some parts of New Bedford Harbor since 1993. The upper and lower ranges for the Upper, Lower, and Outer Harbors for 1993 and 1999 results together with averages for combined stations within each segment for both years are shown in Table 8. This apparent increase of

Cu is most pronounced in the Lower Harbor and may be the result of shoreline commercial and industrial land use and associated marine activities.

Table 8. Comparison of Copper Concentration (µg/g dry wt) Recorded from New Bedford Harbor in 1993 and 1999.

Harbor Segment/year	Highest Cu Concentration	Lowest Cu Concentration	Average Cu Concentrations
Upper-1993	1227	25	611.7
Upper-1999	1270	74	759.4
Lower-1993	2054	27	454.2
Lower-1999	5060	17	675.7
Outer-1993	77.2	1.3	20.2
Outer-1999	77.1	1.4	32.2

Stations 202, 222, 226, and 231 were less toxic than would be expected based on their location. The reasons for this decreased toxicity are not known, especially since there is no similarity in other parameters measured at these stations. Two of these stations (Sta. 202 and 222 had primarily sand and gravel sediments; Station 202 also had low TOC (0.16%) and low total PCBs (0.78 µg/g), but Station 222 had somewhat higher TOC (4.7%) and much higher PCBs (16 µg/g). The other two stations had primarily fine sediments with high silt+clay (71.2 and 66.6% for Stations 226 and 231, respectively), with higher TOC levels (6.4 and 9.2%, respectively) but intermediate levels of total PCBs (11 and 7.7 µg/g, respectively).

The species composition and dominance of the benthic fauna in samples collected in 1999 was very similar to that reported for the baseline samples taken in 1993 (Nelson et al., 1996) and 1995 (EPA, unpublished data). In 1993 and 1999, the Upper Harbor was dominated by three species: the polychaete *Streblospio benedicti* and the bivalves *Mulinia lateralis* and *Gemma gemma*, which together accounted for at least 75% of the total infaunal abundance in 1993 and 1999. In 1995, *S. benedicti, Capitella capitata, G. gemma*, and *Hydrobia totteni* accounted for approximately 75% of the total fauna. Because the 1995 samples were taken shortly after dredging of the "hot spot" sediments, it is likely that the occurrence of *C. capitata* was due to its recruitment into newly disturbed sediments. Like *S. benedicti*, *C. capitata* is an opportunistic species, but its dominance tends to be limited to an early phase of succession. The community dominants in 1993 and 1999, therefore, represent a typical late summer assemblage in an upper estuarine habitat.

The Lower Harbor stations were overwhelmingly dominated by *Mulinia lateralis* in 1993 and 1999; in 1999 this species accounted for 40.2% of the total density. Other numerical dominants, including *S. benedicti*, *Mediomastus ambiseta*, *Mercenaria mercenaria*, and oligochaetes were the same in both years. In 1995, no one species was an overwhelming numerical dominant. Instead an assemblage of *S. benedicti, Tharyx acutus, M. lateralis*, oligochaetes, *Leitoscoloplos* sp., and *Mediomastus ambiseta* characterized the segment. In 1999, the polychaete *Tharyx acutus* was also dominant at Lower Harbor stations.

The Outer Harbor stations were much more diverse than the other areas in all three samplings, but in 1999 the polychaete *M. ambiseta* accounted for 42.9% of the fauna, whereas in 1993 and 1995, it was not as numerically important.

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APPENDIX 1

STATION DATA FOR THE 1999 NEW BEDFORD HARBOR LONG-TERM MONITORING III SURVEY

Appendix 1. Station Data for the 1999 New Bedford Harbor Long-Term Monitoring III Field Program.

Event No.	Visit No.	Sta. No.	Event Date	Begin Time	Event Lat	Event Lat-Min	Event Long.	Event Long-Min	HiTide Time	Depth (m)
5001	1	105	05-Oct-99	14:22	41	40.488	70	54.908	05:13	0.9
5002	1	108	06-Oct-99	10:01	41	40.496	70	54.955	06:05	0.9
5003	1	109	06-Oct-99	08:47	41	40.438	70	54.865	06:05	0.9
5004	1	111	05-Oct-99	11:45	41	40.422	70	54.9	05:13	0.5
5005	1	114	01-Oct-99	13:07	41	40.355	70	54.971	13:33	2.4
5006	1	115	05-Oct-99	15:50	41	40.345	70	54.842	05:13	1.2
5007	1	117	29-Sep-99	09:49	41	40.255	70	55.039	11:33	1.8
5007	2	117	18-Nov-99	12:46	41	40.29	70	55.019	15:35	1.4
5008	1	120	18-Nov-99	11:14	41	40.13	70	55.08	15:35	1
5009	1	121	18-Nov-99	13:35	41	40.154	70	55.003	15:35	1.4
5010	1	123	29-Sep-99	10:19	41	40.016	70	55.034	11:33	2.5
5011	1	125	29-Sep-99	11:38	41	40.01	70	55.098	11:33	3
5012	1	126	29-Sep-99	12:43	41	40.01	70	54.987	11:33	1.5
5013	1	128	29-Sep-99	14:06	41	39.926	70	55.041	11:33	3
5014	1	130	01-Oct-99	14:57	41	39.848	70	55.086	13:33	1.8
5015	1	131	29-Sep-99	15:44	41	39.847	70	54.982	11:33	1.2
5016	1	134	01-Oct-99	16:10	41	39.756	70	55.032	13:33	2.3
5017	1	135	01-Oct-99	11:28	41	39.753	70	54.936	13:33	1.7
5018	1	138	05-Oct-99	08:35	41	39.68	70	55.219	05:13	0.8
5019	1	139	29-Sep-99	08:07	41	39.675	70	55.104	11:33	1.4
5020	1	140	01-Oct-99	10:18	41	39.685	70	54.977	13:31	3.3
5021	1	146	01-Oct-99	08:40	41	39.601	70	54.896	13:31	3.3
5022	1	147	28-Sep-99	12:35	41	39.594	70	54.91	10:41	1.7
5023	1	150	28-Sep-99	10:00	41	39.513	70	55.087	10:41	3.4
5024	1	151	28-Sep-99	14:01	41	39.502	70	54.98	10:41	1.5
5025	1	152	28-Sep-99	08:30	41	39.485	70	54.848	10:41	1.7
5026	1	154	28-Sep-99	16:01	41	39.415	70	55.05	10:41	3.4
5027	1	155	28-Sep-99	11:09	41	39.44	70	54.94	10:41	1.7
5027	2	155	18-Nov-99	14:48	41	39.419	70	54.94	15:35	2.3
5028	2	202	06-Oct-99	12:00	41	39.323	70	55.032	06:05	4.7
5028	1	202	06-Oct-99	12:00	41	39.323	70	55.032	06:05	4.7
5028	3	202	18-Nov-99	08:32	41	39.326	70	55.02	15:35	4.9
5029	1	204	22-Sep-99	15:30	41	39.158	70	55.145	06:13	8.2
5030	1	207	22-Sep-99	14:08	41	38.984	70	55.27	06:13	1.7
5031	1	208	23-Sep-99	08:15	41	38.981	70	55.022	06:58	1.3
5032	1	211	22-Sep-99	13:10	41	38.829	70	55.158	06:13	3
5033	1	212	24-Sep-99	08:50	41	38.826	70	54.906	07:41	3.3
5034	1	216	22-Sep-99	10:48	41	38.66	70	55.023	06:13	2.2
5035	1	217	23-Sep-99	10:21	41	38.662	70	54.781	06:58	3
5036	1	218	27-Oct-99	10:00	41	38.663	70	54.527	10:05	9.5
5037	1	220	22-Sep-99	09:24	41	38.507	70	55.141	06:13	11.1
5038	1	221	24-Sep-99	07:15	41	38.528	70	54.903	07:41	3
5039	1	222	23-Sep-99	12:10	41	38.501	70	54.641	06:58	3.1

Appendix 1. Station Data for the 1999 New Bedford Harbor Long-Term Monitoring III Field Program.

Event No.	Visit No.	Sta. No.	Event Date	Begin Time	Event Lat	Event Lat-Min	Event Long.	Event Long-Min	HiTide Time	Depth (m)
5040	1	224	22-Sep-99	08:10	41	38.338	70	55.269	06:13	10
5041	1	225	21-Sep-99	10:52	41	38.332	70	55.026	17:47	8.8
5042	1	226	21-Sep-99	14:00	41	38.336	70	54.809	17:47	3.5
5043	1	227	21-Sep-99	15:50	41	38.33	70	54.537	17:47	3
5044	1	230	21-Sep-99	09:20	41	38.185	70	55.16	17:47	7.2
5045	1	231	21-Sep-99	08:00	41	38.166	70	54.874	17:47	4.1
5046	1	235	20-Sep-99	14:55	41	38.011	70	55.035	16:58	8.8
5047	1	236	20-Sep-99	16:25	41	38.031	70	54.785	16:58	10.3
5048	1	237	24-Sep-99	10:22	41	38.006	70	54.541	07:41	6
5049	1	240	20-Sep-99	13:16	41	37.873	70	54.91	16:58	10
5050	1	241	20-Sep-99	11:08	41	37.854	70	54.656	16:58	10.2
5051	1	242	20-Sep-99	09:41	41	37.843	70	54.416	16:58	5.8
5052	1	245	19-Sep-99	14:15	41	37.67	70	54.78	16:04	3.4
5053	1	246	19-Sep-99	15:49	41	37.68	70	54.28	16:04	3.6
5054	1	247	19-Sep-99	15:49	41	37.68	70	54.28	16:04	3.6
5055	1	249	19-Sep-99	12:49	41	37.52	70	54.67	16:04	2.4
5056	1	250	19-Sep-99	10:03	41	37.51	70	54.42	16:04	8.8
5057	1	253	20-Sep-99	08:07	41	37.354	70	54.799	16:58	2.6
5058	1	304	14-Sep-99	16:26	41	37.159	70	54.534	23:57	3.1
5060	1	306	14-Sep-99	13:28	41	37.15	70	52.237	23:57	2.8
5061	1	309	07-Oct-99	17:24	41	36.432	70	55.1	06:53	5.2
5062	1	310	14-Sep-99	10:53	41	36.407	70	53.983	11:38	6.4
5063	1	311	14-Sep-99	12:43	41	36.4	70	52.848	11:38	5.5
5064	1	317	07-Oct-99	08:05	41	35.669	70	53.411	06:53	9.8
5065	1	318	10-Oct-99	07:49	41	35.664	70	52.283	09:01	6.6
5066	1	323	07-Oct-99	16:18	41	34.941	70	55.132	06:53	8.4
5067	1	324	07-Oct-99	10:12	41	34.926	70	53.979	06:53	9.9
5068	1	325	10-Oct-99	09:55	41	34.907	70	52.856	09:01	11.8
5071	1	331	15-Sep-99	15:55	41	34.198	70	55.707	12:24	7.3
5072	1	332	07-Oct-99	11:20	41	34.195	70	54.571	06:53	8.5
5073	1	333	08-Oct-99	15:20	41	34.191	70	53.425	07:38	6.2
5074	1	334	08-Oct-99	13:47	41	34.183	70	55.267	07:38	11.3
5075	1	335	08-Oct-99	12:20	41	34.195	70	51.137	07:38	8
5076	1	338	07-Oct-99	12:34	41	33.468	70	55.134	06:53	8.3
5077	1	339	07-Oct-99	15:10	41	33.445	70	53.98	06:53	12.2
5078	1	340	08-Oct-99	09:46	41	33.448	70	52.874	07:38	12
5079	1	341	08-Oct-99	11:08	41	33.439	70	51.729	07:38	11
5081	1	345	07-Oct-99	13:57	41	32.692	70	54.591	06:53	11.6
5082	1	346	08-Oct-99	07:55	41	32.696	70	53.469	07:38	11.9
5083	1	349	15-Sep-99	11:17	41	31.977	70	56.31	12:24	8.2
5085	1	352	15-Sep-99	09:35	41	31.233	70	56.882	12:24	6.4

APPENDIX 2

WATER QUALITY DATA FOR THE 1999 NEW BEDFORD LONG TERM MONITORING III SURVEY

ACUSHNET, MA EARLY ACTION PHOTOS
NEW BEDFORD HARBOR SUPERFUND SITE

BEFORE

AFTER